M.O. 613 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 85, No. 1,008, JUNE 1956

SIR DAVID BRUNT

Born June 17, 1886

I take this opportunity of wishing the Meteorological Office and its staff, and the *Meteorological Magazine* and its readers, long life and prosperity. I have a great faith in the prospects of rapid advances in Meteorology in the near future. The science of Meteorology is rapidly taking on a new guise, and I envy only those who are young enough to be able to see what Meteorology will be like in A.D. 2000.

To readers of this journal I express the hope that they may always be too busy to have time to think of themselves.

DAVID BRUNT

SCHOLAR, TEACHER, ADMINISTRATOR

By SIR GRAHAM SUTTON, D.Sc., F.R.S.

When one considers Sir David Brunt's long and varied career, both as a mathematician and as a practical meteorologist, it is evident that nothing short of a lengthy memoir could hope to do justice to the influence he has exercised on the development of meteorology, not only in this country but throughout the world. On this, the occasion of his seventieth birthday, I propose to comment only briefly and generally on three aspects of his work, in the fields of research, pedagogy and administration, respectively, as a tribute to a man who has done so much for the science of the atmosphere.

Brunt's early training, at Aberystwyth (where he acquired an almost legendary reputation for mathematical skill) and at Cambridge (where he was the Newton Scholar), was that of an applied mathematician, and his approach to meteorology has always been that of the classical mathematical physicist. His work, like that of Rayleigh, Prandtl, and Sir Geoffrey Taylor, is characterized by the ability to solve apparently complex problems easily, without the need to indulge in highly complicated mathematics. Success in applied mathematics depends largely on making approximations by appeals to the underlying physics, and Brunt has always excelled in selecting aspects of a problem of physical significance, and thus getting to the heart of the matter by the shortest route. The "frontal assault" has never appealed to him! There are many examples to be found of this enviable gift, including the well known paper in the *Proceedings of the Royal Society* which amounts to little more than the solution of a quadratic equation, but by way of illustration I can hardly

do better than to cite his classic treatment of the fall of surface temperature on a clear night, a pioneer study that opened the way for many later investigations. At first glance the problem appears to offer little opportunity for a straightforward mathematical investigation, for the nocturnal loss of heat from the ground involves at least four cross-linked factors that are difficult to estimate, namely, long-wave radiation to and from the atmosphere, conduction in the soil, conduction from the air and the release or absorption of latent heat by condensation and evaporation. Brunt's analysis is characteristic in its boldness and effectiveness. The evaluation of radiation flux is rendered amenable by a simple modification of Stefan's fourth-power law to allow for back-radiation from the water vapour in the lower layers of the air, after which the atmosphere itself is eliminated from the problem by the assumption that the surface temperature is mainly determined by the condition that the movement of heat in the soil adjusts itself to maintain a sensibly constant outward flux of heat at the surface. The problem then becomes one familiar in the classical theory of conduction of heat in a solid body, the solution being the well known "parabolic" expression for the fall of surface temperature during the night. Later investigations have followed this lead by making allowance for factors neglected by Brunt, but the improvements in accuracy are not very significant. In a word, Brunt's analysis produced the dominant term and, equally important, revealed at a glance the considerable effect of changes in the physical constants of the soil. The whole work, including the discussion of the water-vapour spectrum, is an admirable illustration of Brunt's use of physical insight with mathematical technique playing, as it should, a subsidiary role, and is characteristic of all his work in dynamical meteorology.

Brunt left the Meteorological Office in 1934 to succeed Sir Gilbert Walker as Professor of Meteorology at Imperial College, London. In the same year there appeared "Physical and dynamical meteorology". It is perhaps a little difficult for the younger generation of meteorologists, with the wealth of texts available today, to realize fully the significance of this book at the time it was published. Those who wished to study meteorology as a branch of mathematical physics in the 20's and early 30's had to rely mainly on Exner's "Dynamische Meteorologie", Humphreys' "Physics of the air" and Shaw's "Manual of meteorology", none of which is ideal for the purpose. Exner's work is extremely academic in its approach and Humphreys' text is too preoccupied with meteorological optics and his dubious theory of "vulcanism" to give the newcomer a balanced view of dynamical meteorology. As for Shaw's Manual, what can one say of this immense work? It is the *magnum opus* of a fine scholar who did more than any other man of his time to make meteorology a branch of physics and ranks today as a classic of our science, but as a technical treatise, or a work of reference for the busy professional meteorologist, it has many shortcomings. Too often it is meteorology in the after-dinner atmosphere of a Cambridge Senior Combination Room—urbane, pleasant and full of facts but, somehow, never quite what one wants in a hurry!

Brunt's work is very different. From the opening chapter ("The facts that call for explanation") it is strongly realistic and carries over into a teaching text the emphasis on a sound physical background that is so characteristic of the author. For the most part the earlier books on dynamical meteorology began with problems in hydrodynamics and sought out examples from the observations as illustrations; Brunt reversed the procedure by starting with 'the

facts that call for explanation', and thereafter selecting from hydrodynamics and thermodynamics only those parts that are significant in the real problems of the atmosphere. The book itself is a delight to read. The style might well serve as a model for writings in science, and although at times the lucidity and ease of presentation tend to conceal the depth of the physical insight, one is conscious always of following the thought of a master craftsman. It is an intensely personal book that reminds one of Brunt's conversation, for the text abounds in phrases that blow away the mists of academic pretentiousness, like the oft-quoted sentence that it is a waste of time to measure air temperature to a hundredth of a degree Centigrade: "the air does not know its own temperature to that degree of accuracy". "Physical and dynamical meteorology" set a new fashion in the exposition of the science of the real atmosphere, and its influence can be traced in most of the textbooks that have appeared since.

In addition to writing this standard text, Brunt built up a strong school of meteorology at South Kensington, and the high reputation enjoyed by the Department of Meteorology of Imperial College today reflects in no small degree the excellence of his work as an administrator in academic circles. The combination of first-class scientific and administrative ability is, unfortunately, somewhat rare, not always because the scientist is lacking in the qualities that make the good administrator but more often because he is inclined to regard the running of the machine as a minor task to be done during intervals of scientific work. Brunt has never made that mistake, and has always given his administrative duties the concentrated attention that ensures success, whether it be in his work as a civil servant, as a professor or as Secretary of the Royal Society. This is well illustrated by the way in which he ensured the creation of a school of micrometeorology in this country from 1921 onwards. After the 1914–18 war the Meteorological Office, newly placed under the Air Ministry, was faced with the double task of assisting in the development of aviation, and of resuming its traditional work of producing daily forecasts and collecting climatological data. Organized research within the Office did not come into being until nearly twenty years later. It was left to Brunt to fill the gap elsewhere, which he did in the somewhat unexpected field of chemical warfare. Gas had played a large part in the war, but it had been used empirically by both sides. In 1920 little or nothing was known of the mechanism of atmospheric diffusion, and the meteorology of the lowest regions of the atmosphere was almost as obscure as that of the stratosphere. The opening of the Chemical Warfare Experimental Station at Porton in 1921 gave Brunt an opportunity which he seized with characteristic vigour. He placed at Porton a small but select team of workers, with the late Sir Nelson Johnson in charge and, as Chairman of the Meteorological Sub-Committee of the Chemical Warfare Committee (a post he held without a break for the next 21 years) he ensured that their programme was broad, fundamental, and never too closely defined—conditions essential for success in any branch of research.

The meteorological work at Porton was often heavily veiled by the Official Secrets Act, and, except for a few highly significant *Geophysical Memoirs* and some papers in scientific journals, remained largely undisclosed until after the Second World War. Even now it is difficult for an outsider to realize, from the published material, how much Brunt contributed to the evolution of micrometeorology as a quantitative science. It must suffice here to say that during his long period of chairmanship, he was the trusted guide, counsellor and friend of all

who took part in the work, and it was in no small part owing to his efforts that when the Second World War came, this country was far ahead of all others in its knowledge of the characteristics of the lower atmosphere and their significance in chemical warfare. But apart from maintaining a wide and flexible programme of investigations, his shrewd management kept the team intact during many difficult periods and laid on those who served at Porton a debt that can never be fully repaid.

When one meets Sir David today, the word "retirement" seems utterly inappropriate for this alert and kindly Welshman is as much at the heart of affairs in the scientific world as ever. He is now, as always, the "happy warrior", a man with friends everywhere and enemies nowhere. But no account of his success, however brief, would be complete without a tribute to Lady Brunt who, educated in the liberal arts, has brought to the social side of the world of science a grace and charm that is entirely her own. To Sir David and Lady Brunt we, their friends in the Meteorological Office, send our sincere wishes for their continued happiness.

POLIOMYELITIS AND WEATHER

By E. N. LAWRENCE, B.Sc.

The affliction known to us today as "polio" or infantile paralysis has recently come into the headlines. It was reported in the press that the Salk experiments in vaccinating half a million children in the United States had shown encouraging results, but that differences, mainly climatic, preclude a definite hope of equal success in this country. Many in these Islands may already hold ideas concerning the relation between weather and poliomyelitis, for the year 1947, when the disease hit Britain badly, was also an outstandingly dry year with an exceptionally cold winter and hot summer—in fact, a year of continental climate. People in Britain had perhaps for the first time become familiar with this dangerous and devastating disease, and for most of us a year of such climatic conditions had not occurred within living memory. The year 1947, though not very dry as a whole, had exceptionally dry individual months—August with 17 per cent. of average rainfall (1881–1915) was estimated to be the driest for 200 yr. The epidemic during the fine dry July and August of 1955, following a fairly cold winter, again drew attention to this subject. When it is remembered also that for many years poliomyelitis has been a dangerous and serious disease in the United States and that in the years just before the war it hit very hard at Switzerland (though without seriously affecting the surrounding countries) the association of the disease with certain aspects of continental climate appears possible. Although the problem has been the subject of extensive research both in Britain and abroad, no definite relation with climate has yet been proved. The reason for this may be that the more important factors are not meteorological. They may include low resistance, due to social or economic causes, or some special immunity as seemed to be experienced by Plymouth in 1947 when it was the only place in Britain to escape the epidemic, notwithstanding that in 1946 it was the only place to experience one. Finally we have to accept the possibility of mere chance infection. Nevertheless the relation between the disease and climate is worthy of investigation.

In 1935 Petersen and Benell[1] associated poliomyelitis with "polar infalls" (indicated by rising barometric pressure) and concomitant changes in the

humidity (lowering), temperature (lowering), storms, wind, etc. They claimed significant comparisons with other diseases—based on the work of de Rudder[2]. Again, in 1951, Wada[3] asserts that there is a close relation between infantile paralysis and atmospheric phenomena. He maintains that the maximum number of notifications is related to preceding high humidity and low rainfall. It is noteworthy that this combination often distinguishes Britain fron continental countries during a hot dry summer.

After the 1947 epidemic, investigations multiplied in this country, and Mr. R. G. Veryard, Assistant Director for Climatological Services, has drawn attention to some unpublished works on this subject. These include data of the broad aspects of weather for a number of years. A study of the salient climatic features for the outstanding years of poliomyelitis incidence in Britain showed that during the three years of very high incidence—1926, 1938 and 1947—the weather was "warm and dry", and that for the year of very low incidence—1918—the weather was "warm and wet", a rather significant result.

Another promising formula (developed in the Meteorological Office and based on data for the period 1933–35 given in the League of Nations Epidemiological Report, October–December 1935) relates the number of days after April 1 on which the average temperature (defined as the mean of daily maximum and minimum temperatures) reaches 55°F. (t) and the number of days from April 1 to the date when poliomyelitis cases reach a maximum (z). This formula, $z = 0{\cdot}63t + 138$, gave a standard error of the estimate of z as 15 days, i.e. (assuming a Gaussian error distribution) there is, approximately, an even chance that for a particular country the maximum will occur within ten days on either side of the date given by this formula. This formula cannot be accepted as truly representative but it certainly shows that climate is a factor to be considered.

In 1949 Dr. C. E. P. Brooks, in a survey of Britain based on the period 1922–47, reached the following conclusions: (1) there is clear evidence of maximum incidence in late summer and early autumn. There is some slight, but not decisive evidence that both minimum and maximum incidence begin earlier in the west and north then in the east and south; (2) there is also some evidence that epidemics which begin in winter are short while those which begin in spring last longest; and (3) although no outstanding effect can be attributed to weather, the following suggestions appear:—

(i) Unsettled months tend to be free of epidemics, especially if there is a good proportion of sunshine (the effect of sunshine disappears in summer).

(ii) Cold autumns tend to favour freedom from epidemics.

(iii) There is little relation to wind direction but there is a slight tendency for epidemics not to end during months of light variable winds.

(iv) A distinct tendency for epidemics to begin shortly after a spell of hot weather.

(v) There is some slight indication that cold spells precede epidemics, possibly because they are quiet and dry, and rooms tend to be overheated.

These were only tentative conclusions.

Throughout the investigations both of the Meteorological Office and others, it has been shown that there is a tendency for poliomyelitis to be associated

with warmth and/or low rainfall. With these ideas in mind, Bradley and Richmond[4], with the help of the Meteorological Office, investigated the meteorological conditions in relation to poliomyelitis in England and Wales for the period 1947–52 inclusive. They studied chiefly dry-bulb temperature and vapour pressure, averaging the daily readings at 3 a.m., 9 a.m., 3 p.m., 9 p.m., to obtain weekly mean values. Their conclusions were as follows:—

(i) Meteorological readings such as these are unlikely to be of material value in predicting the incidence of poliomyelitis.

(ii) The seasonal rise each year did not take place without the attainment of certain minimum values of temperature and humidity. On the other hand, reaching these values did not necessarily mean that the rise began.

(iii) The seasonal fall is not initiated by alterations in temperature or humidity.

(iv) The incidence of poliomyelitis during the season is not influenced to any great degree by variations in temperature and humidity.

(v) In the short period of six years studied there was a tendency for those seasons with the lower average dry-bulb temperature or vapour-pressure readings to show the lowest incidence of poliomyelitis. This could have occurred by chance.

Perhaps these results are a little disappointing but it must be remembered that only six years were considered. Further, only the "pure elements" or

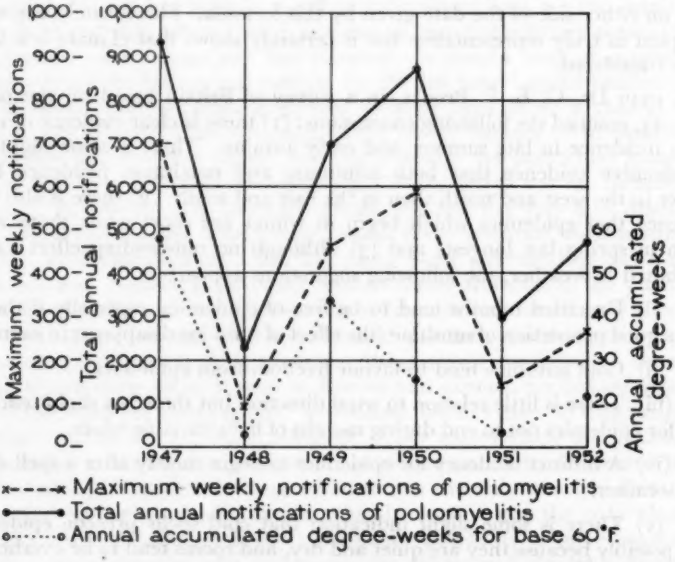

FIG. I—RELATION BETWEEN POLIOMYELITIS AND ACCUMULATED TEMPERATURE IN ENGLAND AND WALES

Based on data given by W. H. Bradley and A. E. Richmond[4].

their simple combination were studied; whereas the more important meteorological parameter may be a complicated function of temperature, vapour pressure or humidity, wind, sunshine, rainfall, etc., —as for example, a measure of evaporation. The writer has computed the correlations of maximum weekly notifications and total annual notifications with annual "accumulated degree-weeks" (computed from the weekly mean temperature in England and Wales) from a base of 60°F.; these correlations of approximately 0·85 and 0·83 respectively (see Fig. 1) are indeed rather striking, for the odds against their occurring by chance are between 20 and 50 to one. In view of these findings, it is suggested that success in other aspects also may be achieved by considering degree-days (temperature), millibar-days (vapour-pressure), or percentage-days (humidity) with reference to a particular threshold value and to a particular period or combination of periods, thus taking into account the sequence of weather characteristics. Increased medical and biological knowledge of the development of the virus might help to select, for the different stages of its growth, the relevant meteorological variables.

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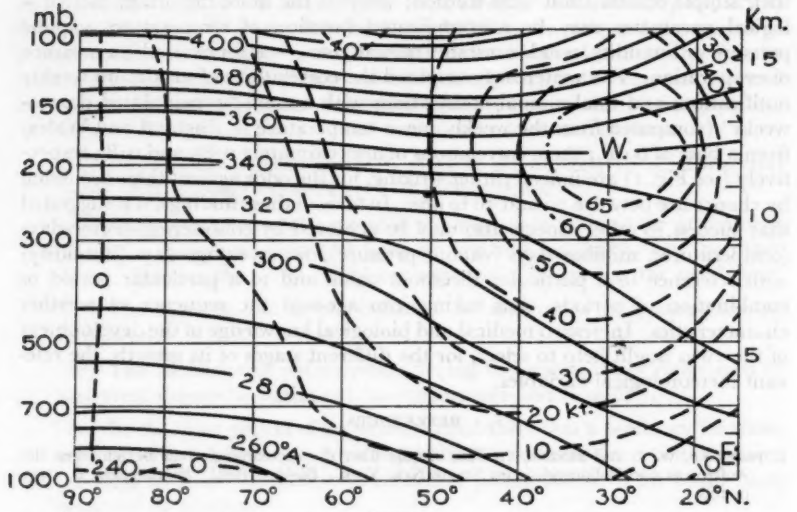
CROSS-SECTIONS OF THE MEAN ZONAL COMPONENT OF GEOSTROPHIC WIND

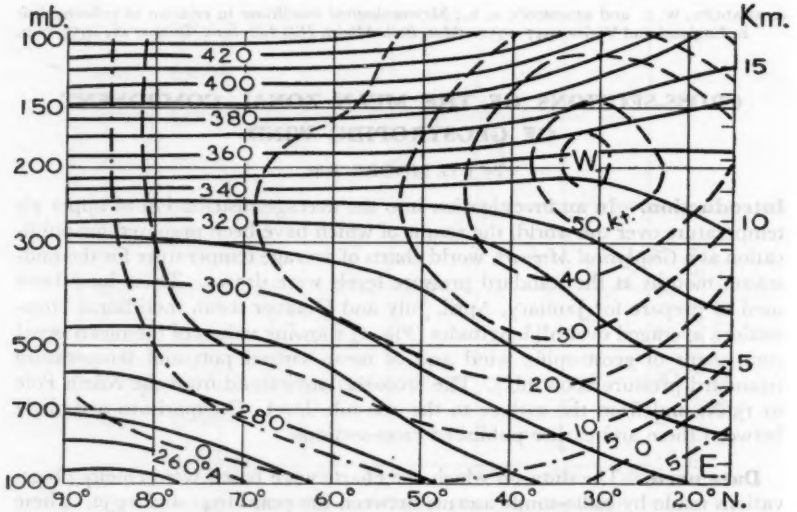
By J. G. MOORE, B.Sc.

Introduction.—In an investigation into the average distribution of upper air temperature over the world, the results of which have been prepared for publication as a *Geophysical Memoir*[1], world charts of average temperature for the mid-season months at the standard pressure levels were drawn. These have been used to prepare for January, April, July and October mean meridional cross-sections averaged over all longitudes (Fig. 1) showing values of the mean zonal component of geostrophic wind and of mean virtual potential temperature (standard pressure 1000 mb.). The cross-sections extend from the North Pole to 15°N. and from the surface to the 100-mb. level. Comparisons are made between these and earlier published cross-sections.

Data used.—The data on which the charts were based were chiefly observations made by radio-sonde ascents between the years 1941 and 1952. These were supplemented by pre-war data from balloon-sonde ascents at some stations in Europe and India and by radio-sonde ascents over the U.S.S.R. In regions where data were few, observations from aircraft were also used up to 300 mb. The number of years for which data were used varied considerably, and no attempt was made to adopt a uniform period, although some adjustment for differences of period was made when drawing the charts.



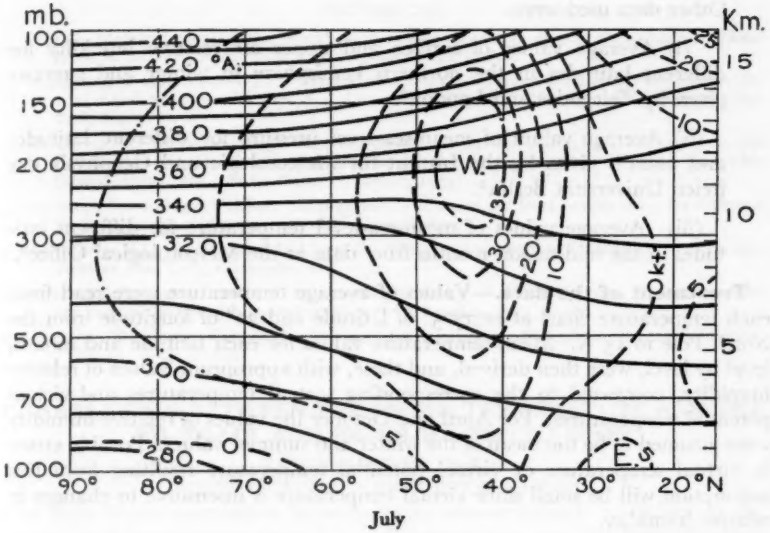
January



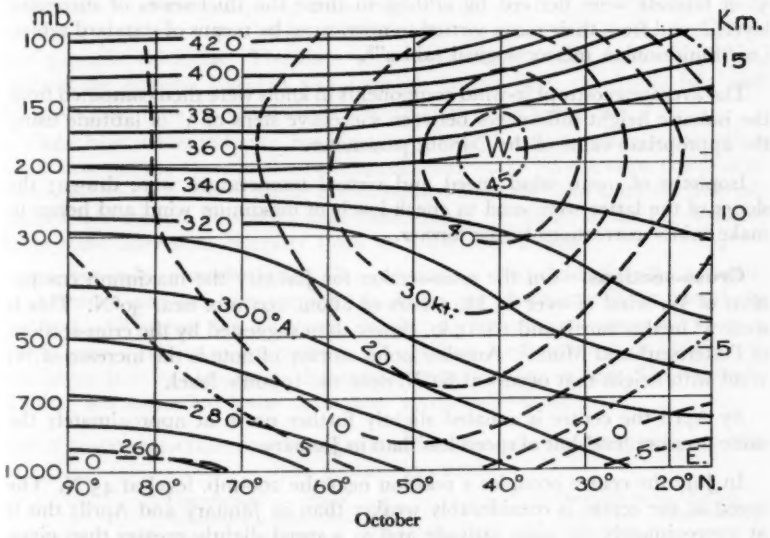
April

FIG. 1—MEAN MERIDIONAL CROSS-SECTIONS

The potential temperature is given by full lines and the mean zonal component of the geostrophic wind by broken lines.



July



October

FIG. 1—*continued*

Other data used were:

(i) Average values of surface and upper air relative humidity for different latitudes in the northern hemisphere in winter and summer given by Telegadas and London[2].

(ii) Average values of mean-sea-level pressure for different latitudes and months given by the Institut für Meteorologie und Geophysik der freien Universität Berlin[3].

(iii) Average values of mean-sea-level temperature for different latitudes in the mid-season months from data in the Meteorological Office[4].

Treatment of the data.—Values of average temperature were read from each temperature chart at every 5° of latitude and 20° of longitude from the North Pole to 15°N. Mean-temperature values for each latitude and month, level by level, were then derived, and these, with appropriate values of relative humidity, converted to the corresponding virtual temperatures and virtual potential temperatures. For April and October the values of relative humidity were assumed to be the mean of the winter and summer values. Possible errors in virtual temperature or virtual potential temperature resulting from this assumption will be small since virtual temperature is insensitive to changes in relative humidity.

Having computed the height of the 1000-mb. level from the average pressure and temperature at mean sea level, the heights of the isobaric surfaces for every 5° of latitude were derived by adding to these the thicknesses of successive layers found from their mean virtual temperatures by means of standard tables, i.e. "Smithsonian meteorological tables"[5].

The average geostrophic-wind components in knots were then computed from the isobaric height differences between successive steps of 5° of latitude using the appropriate value of the Coriolis parameter.

Isopleths of mean wind speed and virtual temperature were drawn; the slopes of the latter were used to check levels of maximum wind and hence to make minor corrections to the former.

Cross-sections.—On the cross-section for January the maximum component of W. wind of over 65 kt. occurs at about 190 mb. near 30°N. This is some 5° further north and 10–15 kt. slower than suggested by the cross-sections of Petterssen[6] and Mintz[7]. Another point worthy of note is the increase of W. wind with height that occurs at 60°N. near the 100-mb. level.

By April the centre is situated slightly further north at approximately the same pressure level but of speed less than in January.

In July the centre occupies a position near the 200-mb. level at 45°N. The speed at the centre is considerably weaker than in January and April; this is at approximately the same latitude and at a speed slightly greater than given on the Petterssen and Mintz cross-sections.

The centre of strong W. wind in October occurs at about the same level as in January and April at 40°N., both position and speed being intermediate to those for April and July.

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CORRELATION BETWEEN THE 500-MB. TEMPERATURE AND THE 500–300-MB. AND 500–400-MB. THICKNESSES

By R. BERGGREN, Fil. Lic.
(Swedish Meteorological and Hydrological Institute)

The high linear correlation between some meteorological variables in the middle and upper troposphere is a well known fact, and has been discussed by many authors[1–4]. Petterssen[1] gives a coefficient of about 0·97 for the correlation between the 500-mb. temperature and the 500–400-mb. thickness. The coefficients are computed from British radio-sonde data. Murray[2] gives coefficients for the correlation between the 500-mb. temperature and the 500–300-mb. thickness. The data used were the material from the British radio-sonde stations Larkhill and Lerwick during January, April, July and October 1947 and the correlation coefficient is as high as 0·97.

These high values indicate that it might prove valuable to compute regression equations and use these in the daily aerological work. As the same coefficients and equations referred to above are computed from the data from the Swedish radio-sonde station Torslanda near Gothenburg (57°42′N. 11°47′E.) it might be of some interest to compare them with the earlier ones.

500–300-mb. correlation.—The correlation coefficients for the 500-mb. temperature and the 500–300-mb. thickness are given month by month in Table I. All values for Torslanda in this paragraph are computed from a 10-yr. series (July 1940–June 1950). The highest coefficient is 0·95 (May) and the lowest is 0·89 (January); the standard error is 0·01 or less. The values in Table I are somewhat lower than those given by Murray[2].

TABLE I—CORRELATION COEFFICIENTS FOR THE 500-MB. TEMPERATURE AND THE 500–300-MB. THICKNESS

	Correlation coefficient	No. of observations		Correlation coefficient	No. of observations
January ...	0·888	291	July ...	0·941	260
February ...	0·913	279	August ...	0·937	257
March ...	0·941	308	September ...	0·940	255
April ...	0·900	294	October ...	0·934	257
May... ...	0·953	291	November ...	0·925	245
June... ...	0·931	283	December ...	0·916	261

The equation for the regression of the thickness on the temperature can be written as

$$a = b_1 T + b_2$$
$$\text{or } a' = b_1' T' + b_2'$$

where a (in geopotential metres) and a' (in feet) are the values of the thickness, T (in degrees Celsius) and T' (in degrees Fahrenheit) are the values of the temperature, and b_1, b_1', b_2, b_2' are constants, whose values are given in Table II.

TABLE II—CONSTANTS FOR THE REGRESSION EQUATIONS OF 500–300-MB. THICKNESS ON THE 500-MB. TEMPERATURE

	b_1	b_2	b_1'	b_2'
	gpm./°C.	m.	ft./°F.	ft.
January	10·63	3781·6	19·37	11787
February...	11·37	3796·3	20·72	11792
March	10·49	3783·5	19·12	11801
April	11·12	3803·7	20·27	11831
May	11·77	3817·3	21·45	11837
June	13·26	3858·3	24·17	11885
July	13·79	3865·5	25·13	11878
August	12·57	3849·1	22·91	11895
September	12·94	3853·2	23·58	11887
October	12·31	3839·0	22·44	11877
November	12·11	3831·2	22·07	11863
December	11·48	3804·7	20·92	11813

The standard errors of the estimate are given in Table III. The corresponding value given by Murray[2] is 20 gpm. (66 ft.) and this is slightly lower than the average value for Torslanda.

TABLE III—STANDARD ERROR OF ESTIMATE OF THE 500–300-MB. THICKNESS

	Standard error	
	gpm.	ft.
January	32	105
February	28	92
March	22	72
April	24	79
May	15	49
June	21	69
July	17	56
August	18	59
September	22	72
October	24	79
November	27	89
December	26	85
Murray's estimate ...	20	66

During the computations it turned out that the monthly regression equations given by the constants in Table II could for all practical purposes be brought together in two groups:

June–November

$$\left.\begin{aligned} a &= 12{\cdot}83\ T + 3849{\cdot}4 \\ a' &= 23{\cdot}38\ T' + 11881 \end{aligned}\right\} \quad \ldots\ldots\ (1)$$

December–May

$$\left.\begin{aligned} a &= 11{\cdot}14\,T + 3797{\cdot}9 \\ a' &= 20{\cdot}30\,T' + 11811 \end{aligned}\right\} \quad \ldots\ldots (2)$$

An overall mean gives

$$\left.\begin{aligned} a &= 11{\cdot}99\,T + 3823{\cdot}6 \\ a' &= 21{\cdot}85\,T' + 11845 \end{aligned}\right\} \quad \ldots\ldots (3)$$

Murray's formula is

$$\left.\begin{aligned} a &= 12{\cdot}88\,T + 3851{\cdot}1 \\ a' &= 23{\cdot}47\,T' + 11884 \end{aligned}\right\} \quad \ldots\ldots (4)$$

In order to see if there are any great differences in the values computed from these four sets of equations Table IV was constructed.

TABLE IV—COMPARISON BETWEEN THE ESTIMATED VALUES OF THE 500–300-MB. THICKNESS COMPUTED FROM THE FOUR FORMULAE

Formula	Temperature: Degrees Celsius −10	−20	−30	−40	Degrees Fahrenheit 20	0	−20	−40
	geopotential metres				*feet*			
(1)	3721	3593	3465	3336	12349	11881	11413	10946
(2)	3687	3575	3464	3352	12217	11811	11405	10999
(3)	3704	3584	3464	3344	12282	11845	11408	10971
(4)	3722	3593	3465	3336	12353	11884	11415	10945
Maximum difference	35	18	1	16	136	73	10	54

From Table IV is is quite clear that the differences are small but not quite negligible. It is interesting to note that the formula given by Murray (4) is almost identical with the formula for the summer and autumn months (1) given in this paper. Furthermore, it is interesting to compare equations (2) with (1) which show a great change from one half of the year to the other.

One effect, which reduces the values of the correlation coefficients discussed here, is that of the variable tropopause. If the tropopause is found at relatively high pressures it is self-evident that the connexion between the 500-mb. temperature and the 500–300-mb. thickness is a poor one.

TABLE V—PERCENTAGE NUMBER OF CASES WITH THE TROPOPAUSE PRESSURE GREATER THAN OR EQUAL TO 300, 350 AND 400 MB. RESPECTIVELY

	Pressure at the tropopause >300 mb.	>350 mb.	>400 mb.
	percentage frequency		
January ...	23	6	1
February ...	16	3	1
March	12	4	3
April	25	8	2
May	12	2	0
June	13	2	0
July	4	0	0
August	5	0	0
September ...	9	1	0
October... ...	8	1	2
November ...	13	1	0
December ...	21	5	1
Murray ...	8	...	...

Table V gives the percentage of cases with tropopause pressure above certain limits. For comparison Murray's value, which is markedly lower is given. To some extent this can be explained by the fact that the year used by Murray (1947) was by no means a normal year. For the Torslanda material the 10-yr. mean of tropopause pressure was 246 mb. but for the months January, April, July and October 1947 it was 237 mb. The difference in the geographical location of the stations used naturally accounts for most of the discrepancy. It is not likely that the difference can be explained by different definitions of tropopause, because the British definition is used in both cases and was probably applied in the same manner.

500–400-mb. correlation.—Table VI gives the coefficients for the correlation between the 500-mb. temperature and the 500–400-mb. thickness for the period 1950–53. For all months these are high, from 0·93 in April to 0·99 in December. These values agree well with that given by Petterssen[1].

TABLE VI—CORRELATION COEFFICIENTS FOR THE 500-MB. TEMPERATURE AND THE 500–400-MB. THICKNESS

	Correlation coefficient	No. of observations		Correlation coefficient	No. of observations
January ...	0·968	236	July ...	0·958	235
February ...	0·984	221	August ...	0·980	240
March ...	0·981	234	September ...	0·976	232
April ...	0·934	231	October ...	0·974	234
May... ...	0·970	231	November ...	0·982	237
June... ...	0·963	229	December ...	0·987	234

The mean regression equation is in this case

$$\left.\begin{aligned} a &= 6{\cdot}43\,T + 1742{\cdot}8 \\ a' &= 11{\cdot}72\,T' + 5343 \end{aligned}\right\} \quad \ldots\ldots (5)$$

The equations given by Petterssen are

January, February

$$\left.\begin{aligned} a &= 6{\cdot}31\,T + 1740{\cdot}4 \\ a' &= 11{\cdot}5\,T' + 5342 \end{aligned}\right\} \quad \ldots\ldots (6)$$

March, April

$$\left.\begin{aligned} a &= 6{\cdot}58\,T + 1746{\cdot}5 \\ a' &= 12{\cdot}0\,T' + 5346 \end{aligned}\right\} \quad \ldots\ldots (7)$$

May, June

$$\left.\begin{aligned} a &= 6{\cdot}69\,T + 1749{\cdot}1 \\ a' &= 12{\cdot}2\,T' + 5348 \end{aligned}\right\} \quad \ldots\ldots (8)$$

July, August

$$\left.\begin{aligned} a &= 6{\cdot}80\,T + 1751{\cdot}6 \\ a' &= 12{\cdot}4\,T' + 5350 \end{aligned}\right\} \quad \ldots\ldots (9)$$

September, October

$$\left.\begin{aligned} a &= 6{\cdot}53\,T + 1745{\cdot}0 \\ a' &= 11{\cdot}9\,T' + 5344 \end{aligned}\right\} \quad \ldots\ldots (10)$$

November, December

$$\left.\begin{aligned} a &= 6{\cdot}47\,T + 1743{\cdot}0 \\ a' &= 11{\cdot}8\,T' + 5341 \end{aligned}\right\} \quad \ldots\ldots (11)$$

The standard errors of the estimate by means of equations (5) are given in Table VII and they are low.

TABLE VII—STANDARD ERROR OF ESTIMATE OF THE 500–400-MB. THICKNESS

	Standard error			Standard error	
	gpm.	ft.		gpm.	ft.
January ...	8	26	July ...	7	23
February ...	6	20	August ...	5	16
March ...	6	20	September ...	7	23
April ...	11	36	October ...	8	26
May... ...	6	20	November ...	6	20
June... ...	8	26	December ...	4	13

If equations (5)–(11) are compared it is obvious that the mean equation given for Torslanda is nearly identical with Petterssen's equation for November and December.

Table VIII gives some values computed from equations (5)–(11). The correspondence between the different values is striking. The greatest deviations are again found at higher temperatures.

TABLE VIII—COMPARISON BETWEEN THE ESTIMATED VALUES OF THE 500–400-MB. PARTIAL THICKNESS COMPUTED FROM THE FORMULA GIVEN IN THIS PAPER AND FROM PETTERSSEN'S FORMULAE

	Temperature						
	Degrees Celsius			Degrees Fahrenheit			
Formula	0	−20	−40	20	0	−20	−40
	geopotential metres			*feet*			
(5)	1743	1614	1486	5577	5343	5109	4874
(6)–(11)	1740–1752	1614–1616	1480–1488	5572–5598	5341–5350	5102–5112	4854–4882

The influence of the height of the tropopause is negligible in this case.

Construction of 300-mb. and 400-mb. charts.—The fact that the regression equations are similar over large areas, which was suggested by Murray, can be used in daily aerological work. If for some reason a rapid analysis is wanted, the following method may be used to get a zero approximation. The method supposes that a 500-mb. analysis is available under all circumstances. The 500-mb. contours are analysed as usual. Instead of drawing the isotherms for −10°, −15°C. . . . . or 10°, 0°, −10°F. . . . . , however, certain temperature values are computed from the regression equations in such a way that they correspond to the thickness contours wanted (the same contour intervals as are used for the 500-mb. chart). If the corresponding isotherms are drawn and added graphically to the contours of the 500-mb. chart, the result is a 300-mb. or 400-mb. chart, which is reasonably accurate.

For the 500–300-mb. partial thickness an isotherm interval of about 3°C. corresponds to 40 gpm., and about 9°F. to 200 ft. The corresponding values for 500–400 mb. are about 6°C. and about 17°F.

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METEOROLOGICAL OFFICE DISCUSSION

Progress in numerical weather prediction

The Meteorological Office Discussion held at the Royal Society of Arts on Monday, March 19 on progress in numerical weather prediction was opened by Mr. E. Knighting.

Mr. Knighting said that he was going to deal mainly with the experiment now being carried out in Washington by the Joint Numerical Weather Prediction Unit. Numerical prediction of the pressure distribution, using electronic computers, has been investigated at different centres since the late 1940's, and this method has shown enough promise to make it perhaps the major subject of research in forecasting. The United States Weather Bureau, Navy and Air Force set up the Joint Numerical Weather Prediction Unit, each body providing the necessary staff, equipment and money, believing the time to be ripe to translate some of the research into a forecasting tool. The Unit's objects are to put numerical weather prediction on an operational basis, to examine the results of the predictions and to find methods of improvement.

The numerical predictions that had been made hitherto had been made *post facto* and at leisure, little heed being paid to the time involved in making the forecast. It is doubtful if the computers which had been used in the earlier stages of development would have been able to deal with the calculation on an operational basis, that is to produce the forecast in a time comparable with that taken by an ordinary forecaster. The Weather Prediction Unit was fortunate in being supplied with a very fast and reliable computer (the I.B.M. 701) which has an electrostatic storage capacity of over 2,000 words, a drum memory of over 16,000 words and additionally uses magnetic tapes which hold virtually an infinite number of words. The opener showed two views of the computing room at the Prediction Unit, commenting upon the compactness achieved compared with the earlier computers.

In order to make a numerical forecast it is necessary to use some crude model which approximates in physical fact to the behaviour of the real atmosphere and which is mathematically simple enough, so that the numerical calculations can be carried out. When the Washington Unit came into existence there were several models available, not very different in their physical content,varying in the mathematical detail. The Princeton Group, using a three-parameter model, had had some success in forecasting strong cyclogenesis in a few cases which are famous in the United States because they occurred on public holidays and gave bad weather in contradistinction to the forecast. The physical basis of this model is simple and corresponds to what is observed in the atmosphere in a gross way; the dynamical assumptions are that the wind is almost geostrophic and almost horizontal so that the hydrostatic equation is obeyed; the thermodynamical assumption is simply that the motion is adiabatic for the period over which the forecast is made, about three days at the most, although this assumption cannot be true over a much longer period. Mr. Knighting sketched briefly on the blackboard the equations which are used, showing that the vertical advection of vorticity had been neglected along with a term which dealt with the distortion of the pressure surface. The most questionable of all the assumptions was that the absolute vorticity, when it appears as a multiplying factor, can be replaced by the vorticity due to the earth's rotation (the Coriolis parameter), for in anticyclonic regions the absolute vorticity is often much less than the Coriolis parameter, becoming nearly zero, while in strong cyclonic motion the absolute vorticity can be several times as great as the Coriolis parameter. It is noted that the approximation is at its worst in the regions where rapid changes are likely to take place.

The integration procedure is carried out on a rectangular mesh placed over a stereographic projection of the northern hemisphere which, as used by the Prediction Unit covered the United States, part of Canada and of the Atlantic and Pacific Oceans. The mesh length varied with latitude, being about 300 Km. in the middle latitudes. In the numerical solution some assumption must be made as to the behaviour near the boundaries of the mesh, and this causes errors to arise which tend to spread inwards. For this reason the forecasts which were finally issued did not refer to the whole area covered by the mesh but to a rather smaller area. The integration is carried out in half-hour time steps, so that if the initial chart corresponds to time t hr. the first forecast refers to time $t + \frac{1}{2}$ hr. Using this forecast as the new initial chart a forecast referring to time $t + 1$ hr. is made, and the process repeated. Most of these forecasts are simply held inside the computer, and eventually lost; those corresponding to 12, 24 and 36 hr. forecasts are printed out. The forecasts are made at the three levels 900, 700 and 400 mb., but interpolation and extrapolation are used to print out the forecasts at the more usual levels, 1000, 700 and 500 mb. Each time step takes about $\frac{1}{2}$ min. so that the whole process takes about $1\frac{1}{2}$ hr. including the printing-out time. Before the calculation can be made the observational data must be transmitted to the Prediction Unit, the charts must be plotted and analysed and the contour heights read off at each of the grid points. At first the plotting and analysis were done by orthodox methods, as used in the British Central Forecasting Office, but later this was done by the computer, which saved some time. The forecasts are available about 8 hr. after the time of observation, about 1 hr. before the orthodox forecaster issues his bulletin, most of the delay lying in the transmission of the observations.

In addition to these "baroclinic" forecasts a "barotropic" forecast was made at the 500-mb. level for periods of 24, 48 and 72 hr. over a much larger area than that covered by the "baroclinic" forecasts, covering nearly the whole of the northern hemisphere. These forecasts were originally intended to help in specifying the boundary conditions for the "baroclinic" forecasts but proved to be of considerable interest in themselves.

Forecast verification has customarily been given in terms of the correlation between the forecast and actual height changes observed at the grid points of the mesh, with the root-mean-square forecast error or a regression equation connecting the forecast and actual height changes. There has never been agreement that this is the best way of presenting the results, and it suffers from the disadvantage that these numbers are not readily interpreted for everyday use. The Prediction Unit decided to present the comparisons in quite a different way. At each grid point one can form the geostrophic wind for both the forecast and verifying charts, and for any other chart with which comparison is desired. It is these geostrophic winds which are compared.

Mr. Knighting showed a series of slides giving some of the statistics which had been computed for the forecasts made during the latter half of 1955. These figures showed that on the whole the 24-hr. forecasts were more successful over the eastern United States than over the area which covered the whole of the United States and parts of the Atlantic and Pacific Oceans. The forecasts seemed to be better at 400 mb. than at 700 mb., and better at 700 mb. than at 900 mb. The forecast error was less than the error which would arise if the winds were forecast to remain unchanged, and substantially so at 400 mb. The mean wind over the whole chart was usually forecast to remain almost unchanged, whereas the mean wind did in fact change with time. The root-mean-square forecast wind error expressed as a fraction of the root-mean-square wind on the verifying chart showed that the forecasts were rather more successful in the autumn than in the summer, and re-emphasized the result previously obtained—that the 400-mb. forecasts are the best and the 900-mb. forecasts are the worst. The "barotropic" forecasts at 500 mb. which were started in late October proved almost as good as the "baroclinic" forecasts at 400 mb. in November and December. The forecasts deteriorate with time, but even after 36 hr. it is usually found that the forecast errors are less than those due to a persistence forecast.

The "barotropic" forecasts at 500 mb. showed almost as good verification figures as did the "baroclinic" forecasts at 400 mb., but the mesh length was twice that used for the "baroclinic" forecasts, and the increase in mesh length tends to smooth out the extreme winds and to decrease the forecast error. The "barotropic" forecasts were verified over five areas, Atlantic, Pacific, United States, Canada and North Pole regions, and showed that over all the areas the forecast error was less than that made by a persistence forecast except for the 72-hr. forecast over the United States. The results showed how the uncertainty of analysis over an area containing few observations, such as the Pacific Ocean, spreads with time so that after 72 hr. the best forecast was found over the Atlantic where initial observations are scarce, and the worst forecast found over the United States where observations are numerous.

The opener said that from a synoptic point of view the numerical forecasts appeared to be quite as good in general as those produced by the more orthodox forecaster, especially at 700 mb. and 500 mb., while at 1000 mb. the general positioning of cyclones and anticyclones was as good as that made in the usual way. The United States Weather Bureau forecaster showed great interest in the numerical forecasts which were available to him about 1 hr. before he issued his forecasts. Notable faults of the numerical forecasts were (*a*) spurious anticyclogenesis which seems to occur in most waxing high-pressure systems and which leads to a serious over-estimation of the pressure—numerical models used so far all seem to lead to spurious anticyclogenesis; (*b*) failure to forecast well in the lee of the Rockies—the model assumes that the ground is flat and makes no allowance for topography, although this can be included; (*c*) failure to forecast what are clearly non-adiabatic processes, e.g. the formation of heat lows over the desert regions in summer; (*d*) a tendency to move low-pressure systems to the left and to deepen them too much—this is not as obvious as the spurious anticyclogenesis.

Finally Mr. Knighting drew attention to the co-operation which had been given by the Prediction Unit. The results contained on the slides were unpublished, and yet the Prediction Unit had made them available for the first time for this discussion. The co-operation was manifest in other ways: sending to us forecast charts and the exchange of ideas. We must be grateful to Dr. Cressman and his associates for their close co-operation.

Mr. D. E. Jones showed two slides of numerical forecasts which had been made by the Prediction Unit for a period of four days commencing October 10, 1955. These slides showed the forecast and actual positions of a low-pressure system moving over the north-east of the forecast map. On successive days the numerical forecast placed the low too far north and underestimated its central pressure. A high-pressure system moving in from the Pacific was also traced, and showed clearly the spurious anticyclogenesis which had already been mentioned.

Mr. Bushby described the work that had been carried out by the Meteorological Office during the past twelve months. A series of numerical forecasts had been made when the official forecasts had proved to be substantially in error. In nearly all these cases the numerical forecast had been essentially correct although in detail there were differences when the level of non-divergence was changed from 500 mb. to 600 mb. Experiments had been carried out using a

stream function in place of the assumption that the wind was related to the contour height by the geostrophic relation. Only in one case was there any marked improvement. Considerable work had been done on objective analysis of the observations, approximating the local shape of the pressure surface by using quadratic and cubic surfaces. Mr. Bushby sketched out the method on the blackboard showing how he proposed to deal with areas in which there were very few observations by using lightly weighted forecast values. He described the new Ferranti Mark II electronic computer which will be acquired by the Meteorological Office in 1957.

Dr. Wilkes asked why the simpler "barotropic" model should give results which are as good as those given by the more elaborate "baroclinic" models. Mr. Knighting said that it was true that "barotropic" forecasts made for the 500-mb. level were about as good as those made at the same level using a "baroclinic" model because the profile of vertical velocity with pressure showed a maximum somewhere in the middle of the troposphere; there $\partial\omega/\partial p$ became zero (where ω is the vertical velocity dp/dt, and p is the pressure). When $\partial\omega/\partial p$ was made zero the baroclinic equation at that level reduced to the barotropic equation.

Dr. Forsdyke asked what assumptions were made in the United Kingdom about the contour heights at the boundaries. Would it be possible to apply the same methods to a grid covering the hemisphere, so getting rid of the lateral boundary conditions? If so, would the systems run down since no energy was being put in? Mr. Knighting and Mr. Bushby replied that hemisphere forecasts had been made in the United States and had been quite good after 3 days. The Stockholm "barotropic" forecasts also covered a great part of the hemisphere. Friction was not included in the model and hence the forecast systems would not run down.

Dr. Forsdyke asked if the spurious anticyclogenesis was due to neglect of friction. Mr. Knighting said he did not know. There were so many things that could cause spurious effects—linearization, neglect of variation of the Coriolis parameter, the use of the geostrophic assumption among them. In an anticyclone the air did flow across the isobars whereas the models kept the air moving along the isobars and this frictional effect could lead to spurious anticyclogenesis, and a similar effect could lead to spurious cyclogenesis. The partial neglect of the variation with latitude of the Coriolis parameter must lead to spurious anticyclogenesis when air was moving northward.

Dr. Sutcliffe asked why the variation was ignored when the "barotropic" forecast depended essentially on it. Did the "barotropic" forecasts show the spurious effect? Mr. Knighting replied that in the model the variation was only ignored in one term and kept in the others. It was not totally neglected. The "barotropic" forecasts did show spurious anticyclogenesis.

Mr. Douglas (Cambridge University) asked why the equations should not be used over the whole of the earth's surface. Mr. Knighting said that there was a difficulty in the region of the equator where the relation between wind and contour height became indefinite. We would need to change our equations in this region. From a practical point of view we could not do this using computers now available and still make a forecast in a sufficiently short time.

Mr. Douglas said that in ten years' time machines would be one or two orders faster than now, and then surely, it would be possible to work from the primitive equations.

Dr. Sutcliffe asked if any problem as complicated as the meteorological problem had been tackled. At any time there were perhaps 50 depressions and anticyclones, and we are now trying to forecast the movement of one or two.

Mr. Douglas suggested using a coarse grid as had been done in other problems.

Mr. Bushby pointed out that if the full equations were to be used one would require the observed initial field of vertical velocity everywhere. It was not possible to measure it, and in general the number of observations over some areas made it impossible to be sure what the actual initial conditions were.

Dr. Eady said it was a matter of time economics. The easiest way of making a forecast was to use the primitive equations but their use demanded a very short time step. We operated on the equations to get rid of the short time step. Using a coarse grid came to much the same thing.

Professor Sheppard asked about numerical rainfall forecasts which were not very good. Is it possible that we can forecast the horizontal fields well but not the vertical fields? If this is so it is very disturbing since we are having to forecast weather which depends so much on the vertical velocity field. Mr. Knighting said that the rainfall forecasts were poor when viewed from the point of view of a single station. The vertical velocity was a mean for a square of side 200 miles in length, and if one took the actual rainfall inside the square and averaged it out the numerical forecast did not look so poor.

Mr. Sawyer remarked that as soon as condensation commenced the adiabatic assumption was falsified by the latent heat. Some calculations showed that the terms which had been left out of the equations of the present models, especially the twisting term, were very important, and it is unlikely that good estimates of rainfall could be made except by treating the smaller-scale motions which were only grossly represented on the grid size that was being used.

Dr. Sutcliffe added that it was optimistic to expect to get even the mean rainfall over a grid square correct when small systems such as thunderstorms occurred within an air stream that might appear stable when viewed in the large.

Mr. Chambers pointed out that the relative errors seemed to decrease with height, and hoped it would be possible to go higher—above the tropopause. The delay in getting the observations to the forecast centres was very important, and forecasts would be much improved by knowing what was going on at present. He instanced an error in the forecast movement of a depression which turned to the right of the expected track, saying that had the complete observations been available the forecast would have been much better.

Mr. H. H. Lamb asked if it was possible to say in what particular areas of the synoptic map the forecast errors are most likely to take place, for example in areas of heating or of strong winds. Mr. Knighting replied that the forecasts could be improved by inspection in certain places, such as including heat lows in summer. On the whole the summer of 1955 in the United States had been rather quiet with the quickly moving systems to the north and near to the grid boundary, so that it was not easy to say if regions of strong wind were particularly susceptible to error, although the non-geostrophic effect might be larger there.

Mr. Bushby mentioned that the "baroclinic" forecasts made in the United Kingdom allowed for the non-adiabatic heating which occurred in northerly outbreaks of cold air over the Atlantic. The non-adiabatic term was inserted using the results obtained by Mr. Craddock, and improved forecasts were obtained.

Mr. Turner asked if the spurious anticyclogenesis was more marked in particular geographical areas such as over Sweden or Greenland. Mr. Knighting replied that the effect seemed to occur anywhere.

Dr. Sutcliffe in summing up said that no one interested in meteorology could fail to be interested in the new methods which combined more data, better computers and people with ideas. Much more work was required to decide statistically where the numerical forecasts were best and where they were likely to go wrong. The old methods of forecasting did not give any idea as to why the forecast was in error, but in the numerical forecasts it was possible to start with simple models and trace the error to the neglect of certain terms. The simple model gave about as good an answer to the questions we were asking as did the more complex models, and this may be because over the period for which the forecast is made, a day or so, the atmosphere moves coherently.

OFFICIAL PUBLICATIONS

The following publications have recently been issued:

PROFESSIONAL NOTES

No. 119—*High cloud over southern England.* By R. J. Murgatroyd, B.Sc. (Eng.) and P. Goldsmith.

Data are presented of the frequencies of occurrence of high cloud over southern England, diurnal and seasonal variations, types of high cloud, heights and temperatures of bases and tops, thickness, visibility, and humidity in its vicinity. These data are based on surface observations and six years' high-level ascents by aircraft of the Meteorological Research Flight. The relation between the persistence of condensation trails and the presence of high cloud is discussed. Finally some mechanisms are suggested for the formation of high cloud over the British Isles.

No. 120—*Distribution of wet-bulb temperature at Aberdeen and Eskdalemuir.* By A. B. Thomson, M.A.

This paper outlines the results of an analysis of hourly wet-bulb temperature at Aberdeen and Eskdalemuir. Monthly, seasonal and annual distributions are shown, on a percentage basis, in tables and diagrams. Consideration is given to the determination of the approximate distribution of wet-bulb temperature at other places in Great Britain.

WORLD METEOROLOGICAL ORGANIZATION

Second Session of Regional Association VI (Europe)

The Second Session of Regional Association VI (Europe) of the World Meteorological Organization took place at Dubrovnik, on the Adriatic coast of Yugoslavia, during March 12–24, 1956, under the chairmanship of the President of the Association, Professor Lugeon, Director of the Meteorological Service of Switzerland. It was attended by 71 delegates from 30 Member countries, and a number of observers. The United Kingdom delegation of four, consisting of three from the Meteorological Office and one from the Naval Weather Service, was led by Mr. S. P. Peters, Deputy Director (Forecasting) of the Meteorological Office. The Secretary-General of the World Meteorological Service, Mr. D. A. Davies, was present during the first few days of the Session. The opening plenary Session was attended by His Excellency the Minister Plenipotentiary Dr. Jaksić who delivered an address of welcome to the delegates on behalf of the Yugoslav Government.

For the conduct of the detailed work of the Session, two committees were established, one under the chairmanship of Mr. C. V. Ockenden, of the United Kingdom delegation, to deal with those items on the agenda involving the international exchange of data, and the other, under the chairmanship of M. Bessemoulin, of the French delegation, to handle other questions. Of the 48 or so Resolutions and Recommendations approved in plenary sessions some mention may be made of the more important ones.

At the Washington Session of the Commission for Synoptic Meteorology in 1953, the question of the times of upper air observations was considered, and it was noted that certain scientific advantages might be obtained by having these observations synchronous with the primary surface observations, but the practical aspects of the then existing situation required the realization of this objective to be postponed. That Commission considered, however, that Regional Associations should continue to study the problem, in order to provide recommendations for its guidance at the next session. Accordingly, this question was included in the Agenda for the Second Session of Regional Association VI, and the result of its examination was agreement to recommend that the standard hours be fixed at 0000, 0600, 1200 and 1800 G.M.T., the Executive Committee being invited to consider the question as a matter of urgency and to seek the approval of Member countries by correspondence. It was felt desirable that the change should be made in time to be effective during the forthcoming International Geophysical Year.

A requirement for a wider dissemination within the Region of upper air data for high levels resulted in the adoption of a Resolution that the levels of 150 and 100 mb. shall be standard isobaric surfaces in the Region. In order that the inclusion of data for these levels in aerological reports should not cause undue delays in dissemination of upper air data, it was agreed that messages containing these data should be divided and transmitted in two parts, the first part containing reports up to the 100-mb. level inclusive, and the second part information for all higher levels. It was also decided that the time of launching of balloons shall be 0200, 0800, 1400 and 2000 G.M.T. (as long as the present standard times for these observations remain unchanged), and that the filing time for the first message shall not be later than two hours after the launching of the balloon, every effort being made to reduce this interval to the minimum possible.

Although the subject of forecasting for high-level flights was included on the Agenda, no opportunity was afforded for the discussion of actual forecasting techniques, and it seemed that only a few countries represented had, as yet, sufficient experience in this field to be in a position to make any substantial contribution to such a discussion in respect of levels above 300 mb. It was, therefore, resolved to invite Members of the Region to inform the World Meteorological Organization Secretariat regarding these aspects of forecasting for high-level flights on which they considered it desirable to have an exchange of opinion. The information so obtained would be circulated to all Members of Regional Association VI for comments, and the President will then, at his discretion, convene a meeting of experts from Member countries interested to examine the problems raised.

The subject of the preparation of climatological atlases on a regional basis gave rise to considerable discussion. Many delegates thought it premature to consider preparing such atlases whilst a number of countries were still deeply engaged in constructing national atlases. Notwithstanding that a Working Group on Climatological Atlases has been established by the Executive Committee, it was decided to set up a Working Group within Regional Association VI consisting of representatives of Sweden, Austria, Italy and the Federal Republic of Germany to advise the Executive Committee's Working Group regarding particular problems arising from the preparation of national atlases within Region VI.

The importance of correcting radio-sonde observations for radiation errors as a means of improving the homogenity of these observations within the Region was recognized, and it was decided to recommend that the World Meteorological Organization Secretariat should request Members to notify the Secretariat of the nature of the radiation corrections currently applied in their respective Services, and to state, if no corrections are made, whether they plan to introduce such corrections before the beginning of the International Geophysical Year on July 1, 1957. The results of this inquiry would be distributed to Members of the Organization and also to the President of the Commission for Instruments and Methods of Observation, for further study.

The problem of the measurement of the radio-activity of precipitation and of the atmosphere was considered, and it was decided that, since this matter is one of practical and scientific interest to Members, notwithstanding that observations made may not be directly used in the activities of all meteorological services, Members should be invited to arrange as far as possible for their Meteorological Services to participate in the making of such observations, taking into account the interest of public health organizations in this matter, and encouraging close co-operation between meteorological services and other organizations interested in radio-activity.

For the past five years the Netherlands Meteorological Service has been required to meet an increasing demand for temperature forecasts for several places abroad. In particular, international transport companies operating in the Netherlands are interested in such forecasts in

connexion with the transport by land, sea or air of perishable goods such as bananas, potatoes and flour, and temperature forecasts for Belgium, Czechoslovakia, Denmark, France, Germany, Italy, Norway, Sweden and the United Kingdom are now prepared daily on a routine basis. The Netherlands delegation accordingly invited a discussion on the question of whether a system for the exchange of temperature forecasts similar to that which operates in regard to landing forecasts for aviation might be introduced. Stations in the United Kingdom in respect of which forecast temperatures are being supplied by the Netherlands Meteorological Service are Glasgow, Liverpool and London. As a result of the discussions a Resolution was adopted specifying the code to be used for the exchange of these temperature forecasts, and Members requiring such forecasts from other Members will arrange for their exchange on the basis of bi-lateral or multi-lateral arrangements.

In the field of telecommunication, one of the interesting features is the recognition by a large majority of countries that the exchange of meteorological data by Morse radio is well on its way to becoming a thing of the past so far as Europe is concerned. The emphasis now is on the use of teleprinter circuits and broadcasts, both land-line and radio, not only because teleprinter technique is almost three times faster, but also because it lends itself so easily to automatic tape-relay operation. Since January 1, 1956 the broadcast from New York has been by radio-teleprinter, and Australia has also adopted this form of transmission, but it was hardly expected that so many European countries would show as much readiness to extend the use of the newer form of communication for meteorological purposes as they did at Dubrovnik.

One resolution adopted at the Session called for a study by the principal "sub-continental" broadcasting centres of the best means of implementing radio-teleprinter transmission broadcasts; these may eventually take the place of the existing Morse broadcasts which have been in operation for the past quarter of a century. Another re-emphasized the economy which would be effected both in transmitters and radio-frequencies if those countries which have a relatively small amount of data to disseminate were grouped together. One country would undertake to make a single combined broadcast to replace three or four separate "territorial" (previously known as "national") broadcasts. Another recommendation related to the need for a detailed investigation to be made of all communication channels now used in Europe both for the exchange of basic synoptic bulletins and data required specifically for aeronautical meteorological purposes. Such an investigation will require very considerable research in the available facilities and the collection of material which would need to be put before a special joint meeting of the World Meteorological and International Civil Aviation Organizations. It is highly probable that the use of land-line teleprinter circuits will be exploited to the full, and that Morse radio broadcasts will be limited to those cases where no other means of exchange can be utilized.

Perhaps the most striking Resolution, however, was that containing a decision that the teleprinter network which has functioned so well in western Europe, with focal points at Dunstable, Paris and Frankfurt, and familiarly known as "IMTNE" (International Meteorological Teleprinter Network in Europe) should be linked with a network which comprises circuits between Prague, Potsdam, Budapest, Warsaw and Moscow. Details of the connexion, the circuit to be adopted and schedules for the exchange of meteorological information have still to be worked out, but the final outcome should lessen very considerably the necessity for main meteorological centres having to depend on the interception of outmoded hand-speed Morse radio broadcasts. A suggestion was made at the Dubrovnik meeting that one link between the two teleprinter networks should be between Frankfurt and Prague. Countries which are served by the existing Western European Network are France, Belgium, Netherlands, United Kingdom, Italy, Switzerland, Denmark, Norway, Sweden, Western Germany, Austria, Finland and Ireland*.

The exchange of weather maps by facsimile was also discussed at some length at the Session. It was recognized that this technique particularly lends itself to the reception of actual and forecast analysis charts covering a wide area. Telegraphy involves the laborious coding and decoding of a vast number of selected points on curves for many levels of the atmosphere, and the resultant drawings, based as they must be on the limited amount of data (number of points) for which transmission time is available, are often far from satisfactory. Facsimile provides the recipient with a chart identical with that prepared at the analysis centre without the expenditure of any man-power or time in decoding and plotting. The following European countries are already making use of facsimile either operationally or experimentally: Austria, Belgium, Denmark, Greenland, Finland, France, Germany, Italy, Norway, Sweden, United Kingdom, U.S.S.R. The meeting agreed to a resolution asking that existing broadcasts be continued and that all main "sub-continental" centres should ultimately provide scheduled broadcasts. It is obviously of paramount importance at this stage in the development of facsimile that apparatus produced in various countries should be compatible. A working group produced specifications for standardization based principally upon meteorological requirements, and it was agreed that these should be presented to the appropriate Study Groups of the International Telegraph Consultative Committee as a contribution to their studies of the technical considerations involved.

* OCKENDEN C. V.; A new international meteorological communications centre at Frankfurt. *Met. Mag., London*, 83, 1954, p. 122.

It is, of course, difficult to forecast the rate of progress in the fields of radio-teleprinter and radio-facsimile transmissions, but it may be that, even in two years' time, main meteorological collecting centres will no longer require to receive messages in Morse except from isolated locations and weather ships, and that material for the whole of a hemisphere will be collected by the use of only a very few receiving aerials. The integration of the requirements of the different Regions of the World Meteorological Organization is, of course, a matter for the Commission of Synoptic Meteorology, and it is probable that its Working Group on Telecommunication will, as a result of Regional developments, be in a position to recommend very substantial modifications to the "continental", "sub-continental" and "territorial" Morse broadcasts which have served so well in the past but which are now having to be replaced by more mechanized techniques. The advent of numerical forecasting methods is one factor which has emphasized the requirement for exchanging raw data within a wide area with a much higher speed than has hitherto been necessary; another factor is, of course, the increasing use of high-speed jet aircraft both for civil and military purposes.

At the conclusion of the session Dr. A. Nyberg (Sweden) was elected President in succession to Professor Lugeon, and Mr. Perović (Yugoslavia) was elected Vice-President.

LETTER TO THE EDITOR

An unusually smooth wave pattern in a condensation trail

In his article in your February issue on the deformation of a condensation trail in a series of lee waves Mr. Harper states with regard to standing waves, that "increase of wind with height in the lower layers of the air stream, and the presence of a deep isothermal layer are very favourable for their development". Although I am sceptical about Mr. Harper's explanation of the form of the trail he saw, because I do not think that standing waves of the amplitude he requires would have been set up, I found his discussion of what would happen to a trail in waves most interesting.

However, the statement he makes about conditions for lee waves is not correctly applied in the instance in question. Theoretical justification for the statement is based on the assumption that in the layers of strong wind (or, more correctly, of small value of l) the amplitude of the waves decreases upwards so that at levels above the tropopause, for instance, where l increases again, the amplitude is quite negligible. Perturbation theory cannot at present be applied to the layers in which l increases upwards to great heights and is only applicable to the lower layers, as in the case reported upon by Mr. Chambers in the article following Mr. Harper's, and the observations confirming the theoretical ideas have all been made in the lower layers of air well below the wind maximum.

Imperial College, London, March 23, 1956. R. S. SCORER

[I gladly accept Dr. Scorer's warning that there is as yet no support from theory for the occurrence of standing waves in the higher layers of the atmosphere. I included the l^2 profile as evidence that conditions were favourable for standing waves in the lower layers. This was admittedly not evidence that they could occur at higher levels, but conditions in the lower layers unfavourable for standing waves would of course have been strong evidence against the possibility.—W. G. HARPER.]

NOTES AND NEWS

Storm at Tengah, December 21, 1955

At 1606 local time (0836 G.M.T.) on December 21, 1955 a squall lasting almost 1 min. moved across the airfield at Tengah from north-east to south-west.

During the period of the squall the following phenomena occurred.

Surface wind rose suddenly to 40 kt. having been north-easterly 2–4 kt., 1·4 mm. (0·05 in.) of rain was recorded, almost all of which fell in 30–40 sec., i.e. at a rate between 125 and 170 mm./hr. (or between 5 and 6·5 in./hr.).

Atmospheric pressure fell 1mb. instantly followed by a period of steadiness, and then the normal diurnal fall continued.

Temperature fell instantly from 85°F. to 80°F. Relative humidity rose from 54 to 84 per cent. (approx.).

The state of the sky immediately before and after the storm was as follows:

Before.—Two oktas, fair-weather cumulus, base 2,500 ft. tops 5,000 ft., scattered generally over the whole sky but with a greater concentration between north and east.

After.—Three large clouds, cumulus or cumulonimbus, base 1,500 ft. tops above 20,000 ft. in the following positions relative to the airfield: one 5–10 miles to the west-north-west, one 5–10 miles to the south and one 3–5 miles to the south-east. Four oktas altocumulus scattered generally over the whole sky.

The upper winds at 1630 local time over south Malaya were 20–40° 15–20 kt. at 3,000 and 5,000 ft. and 340–360° 5–10 kt. at 10,000–20,000 ft.

The storm itself passed over the airfield at about 30 kt. The rain for a very short period, a matter of seconds only, was torrential, reducing the visibility to 500 yd. or less, but at no time did there appear to be any cloud above the storm or up wind of it apart from the fair-weather cumulus. The large cumulus and cumulonimbus previously mentioned were visible long after the storm had disappeared and were moving much more slowly.

These phenomena were observed by several witnesses including a meteorological observer who was off duty at the time, the Duty Air Traffic Control Officer, and a pilot who was landing at the airfield at the time of its occurrence. All agreed that there was no cloud above the storm itself which, after crossing the airfield, either dispersed or went out of sight to the south-west.

P. W. SHORNEY

February 1956—a very cold month in Western Germany

February 1956 was a notably cold month in most parts of Europe and this was particularly true in Western Germany where the severe cold was a complete contrast to the relative mildness of December and January.

The month opened with two days of very severe cold weather. Maximum temperatures on the 1st were exceptionally low and were the lowest recorded during the month at all meteorological stations in north-west Germany. At many stations in the eastern part of north-west Germany the maximum temperature was no more than 5°F. and did not exceed 8°F. at Wildenrath in the western part. After a relatively mild spell lasting from the 3rd to the 8th during which several stations reported maximum temperatures of above freezing point, very severe weather returned on the 9th. From the 9th to the 26th only three stations, Sylt, Wahn and Wildenrath recorded a temperature above freezing point. Milder weather developed on the 27th–29th with maximum temperatures on the latter date ranging from 37° to 45°F.

The lowest temperature of the month occurred during the second severe spell; on the night of the 15th–16th at most stations in the area. The exceptionally low temperatures reported on this night were much lower than any experienced in the ten previous winters. One of the coldest places was Fassberg with a minimum temperature of −15°F. while many stations reported minima within the range −5° to −12°F. These may have been record low temperatures in many parts of the area, although it is difficult to be certain for no pre-war records are available for many of the present stations and little climatological data are as yet readily available for the period 1930–45. However, comparison with some data available for the approximate period 1881–1930 would suggest that the February 1956 minimum temperatures recorded in the western part of north-west Germany are lower than any given in the records so far available. For the eastern and northern parts of the area, lower temperatures were probably recorded in 1929 and possibly in 1881.

The unusual severity of the weather is reflected in the high number of ice days reported during the month, i.e. days on which the maximum temperature did not exceed 32°F. With one exception, Laarbruck with a total of 16, all stations reported between 20 and 25 ice days in the month. These figures may be compared with a 50-yr. average February figure of 4–5 days/month for a representative selection of stations in western Germany.

Finally, although probably not making any contribution to temperature records created during the month, it is interesting to report the very large daily range of temperature recorded at Fassberg on the 25th and at Wahn on the 26th. It amounted to 40°F. in both cases.

REVIEWS

Surveys in mechanics: G. I. Taylor 70th anniversary volume. Edited by G. K. Batchelor and R. M. Davies. 8½ in. × 5½ in., pp. viii + 475. *Illus.*, Cambridge University Press, 1956. Price: 50*s*.

It was a happy thought of Dr. Batchelor and Prof. Davies to bring out this volume of essays, a specially bound copy of which was presented to "G. I." at a dinner in Trinity College, Cambridge, on his seventieth birthday, March 7, 1956. Sir Geoffrey Taylor is our leading classical mathematical physicist, a scientist in the great tradition of Kelvin, Stokes, Maxwell and Rayleigh, and the "surveys of the present position of research in some branches of mechanics" which make up this volume reflect the wide range of subjects to which he has added significantly. In addition, he is an ingenious and skilled experimenter, and it is appropriate that the frontispiece of this book shows him, characteristically, making an adjustment to apparatus which, one suspects, is concerned with a problem in fluid motion, was probably made up of bits and pieces at very low cost, and works perfectly!

The book opens with a brief delightful biography by Sir Richard Southwell. There follow three essays on the physics of the solid state: on plastic deformation by Hill, on dislocations in crystalline solids by Mott and on stress waves in solids by Davies. But the real love of Taylor's life is fluid mechanics, and this is well covered by contributions from Squire on rotating fluids, Lighthill on sound waves of finite amplitude, Lane and Green (of the Experimental Station, Porton) on drops and bubbles, Ursell on wave generation by wind,

Batchelor and Townsend on turbulent diffusion, Ellison on atmospheric turbulence and finally K. S. M. Davidson (of New York) on the mechanics of sailing ships and yachts. There is something here for everyone who is interested in classical physics, but for obvious reasons this review will be confined to topics of interest in meteorology.

Lane and Green give a comprehensive and most useful review of existing knowledge on drops and bubbles, beginning with an account of the shape and (laboratory) production of drops and proceeding to a discussion of terminal velocities of water drops in air. Very minute drops obey Stokes' Law, larger drops behave like rigid spheres up to about 1 mm. diameter, but drops bigger than these are subject to deformation (which increases the drag) and to internal circulation (which causes slip at the boundary and a reduction in drag), and exact calculation is not feasible. The accurate measurement of terminal velocities is a difficult problem, but values tabulated in this essay show that there is now substantial agreement between the various experimenters. The earlier determinations of Lenard, Schmidt and Flower, which have appeared so long in meteorological literature, may now be disregarded, and Best's simple empirical formula for terminal velocities can be looked upon as sufficiently accurate for most practical purposes. The remainder of this well written contribution deals with the break-up of drops by air streams, impact on solid bodies and the dynamics of bubbles.

Ursell's essay on wave generation by wind gives a useful critical review of the various theories that have been advanced in this difficult subject and, in addition, discusses the "roughness" (in the aerodynamical sense) of the sea. The need for more accurate determinations of velocity profiles over the ocean is emphasized, but this is an exceedingly difficult problem for meteorologists, and progress is doubtful.

"Turbulent diffusion", by Batchelor and Townsend, is in the main a digest of recent mathematical papers by Batchelor, with illustrations from the measurements of Townsend and others (chiefly in America) on diffusion in pipes and behind a grid in a wind-tunnel (decaying homogeneous turbulence). This is "basic research" in the true sense, not always easy to follow because of its abstract nature and the condensation into essay form, but obligatory reading for anyone who wishes to make headway in this difficult subject. The application to the atmospheric problem is not immediate, as the authors point out, but the insistence on postulates of a fundamental nature and the emphasis on mathematical rigour are salutary, and this admirable essay may well become a much quoted reference in the future.

The account of current research on atmospheric turbulence by T. H. Ellison is hardly likely to satisfy the professional meteorologist, for it repeats much of what is now commonplace in meteorological texts, and unfortunately, is often misleading regarding what has happened, and is happening, in meteorological research. The article is concerned mainly with the velocity field near the surface. The problem of the approach to the geostrophic wind with the eddy viscosity varying with height is dealt with as if it were new; actually, complete mathematical solutions were published over twenty years ago by Köhler (one-layer power-law formulation) and by Rossby and Montgomery (two-layer formulation), but neither memoir is mentioned. The discussions of the recent work of Sheppard and others on winds in the friction layer, and of the effects

of stability on the profiles, are excellent, but the same cannot be said of the account of the turbulent velocity fluctuations. Here the author reverts to the early bi-vane investigations of Taylor and Scrase, and states that "no definite dependence on stability was found", but he omits to explain that this is because Scrase carefully restricted his observations to occasions when stabilizing forces were absent. For a detailed study of the effects of temperature gradient one must go to Best's well known *Geophysical Memoirs* No. 65, published in 1935, but this work is ignored, and there is no mention of recent American studies of the spectrum of turbulence. Further, the most reliable data show that equality of the lateral and vertical eddy velocities is reached at a height between 20 and 25 m., and not at 25 ft. as stated in this essay. The meteorologist will rub his eyes when he reads the categorical statement that "Findeisen (1936) and Gödecke (1935) were the first to use hot-wire anemometers in the atmosphere"; actually, Albrecht published a description of his instrument in 1930, Best used a hot-wire anemometer in 1931, and, if the point were of importance, a little diligent search of the literature would doubtless produce even earlier examples.

The account of heat transfer is inadequate as an expression of modern trends in this research (restriction on space may, of course, account in part for this) and it includes a speculation on the relation between air and surface temperatures which is very unlikely to be true. Current research in micrometeorology is moving away from artificial concepts such as *austausch* coefficients, and is much more concerned with direct measurements and interpretations of the fluxes and the fluctuations in its attempt to construct a reliable working model of atmospheric transfer processes. The essay fails to bring this out, and may well leave the impression that the meteorologist is still somewhere in the Stone Age of physics!

"G. I." is a renowned yachtsman, and it is appropriate that the book concludes with a delightful informative essay by Davidson on the aerodynamics of sailing and the factors that make for high efficiency in racing yachts. Even non-sailors will find this interesting and rewarding reading.

The book is produced in conformity with the high standards of the Cambridge University Press, but it is a pity that the editors did not see fit to include an index, for the ground covered is immense and the book is likely to prove a useful work of reference.

O. G. SUTTON

Realms of water. Some aspects of its cycle in nature. By P. H. Kuenen. 9½ in. × 6½ in., pp. 327, *Illus.*, Cleaver-Hume Press Ltd, London, 1955. Price: 35*s*.

Modern highly organized societies, though always tending to take for granted any well run communal service, are slowly becoming more hydrosophic or water-wise. This is understandable and not before time. Rapidly increasing demands for enormous supplies of water for domestic and industrial use, for hydro-electric power, and for irrigation, have begun to impose a severe strain even in lands where large-scale water-supply undertakings have a long history of successful achievement. The difficulties experienced during an unusually dry period are still not widely enough appreciated outside the domains of water-supply engineers and their professional associates, but we may yet reach a stage where most of us, having the necessary knowledge forced on our attention, will be actually afraid of a really fine summer. (It should be remembered that the magnificent summer weather of 1955 in Great Britain,

which resulted in water shortages and reduced yields of important crops, including potatoes, did not begin until early July.) Moreover, in nearly all the under-developed regions of the earth a copious and controllable supply of water is the basic requirement before there can be any significant development of agriculture or industry, or any appreciable improvement in the standard of living.

Leaving out of account, at present, problems concerned with snow and ice or with water in the oceans, all with some bearing on human activities, the other side of the picture is that flood hazards are not abating. Whether or not there has been, of late, either a cyclic or non-cyclic increase in the frequency of the catastrophes with which man is troubled, it is beyond doubt that, by building on or otherwise developing or reclaiming land which in earlier times was relatively left alone, he is putting himself in ever larger numbers in the direct natural path of both tidal and river floods—without always being able to take adequate precautions to ensure that their destructive power can be kept within controlled bounds. Concurrently, through highly developed means of communication even the most distant neighbours can be kept informed of what is happening, and we have long been accustomed to learning, without much delay, about floods in China, India and the United States, as well as in Holland and on the east coast of England, or in Lynmouth and Weymouth. If this is not enough, the man-made problem of storm-water drainage in imperviously paved urban areas can, for some of us, bring a milder nuisance to (and over) our own doorsteps.

In recent decades there has therefore appeared a growing international literature, mainly technical and scientific, relating to hydrology and kindred studies. It is perhaps inevitable that this will be followed by a festive season for the popularizers and (probably even worse) the producers of semi-popular works. Both the fully popular and the semi-popular are dangerous fields in which to operate. The few successful products are likely to give long and valuable service, but any specimen from the remainder is equally likely, after a short time, to be displayed as a "book bargain" at a smallish fraction of its original price. For complete success an author must have an understanding which is broad as well as deep, for he must be capable of a sound appreciation of both the minds from which he learns and those he hopes to instruct, and he must also have a command of language enabling him to combine accuracy of information and precision of style with a compelling clarity or even simplicity—but without patronizing naïvety or whimsy. It is a further advantage if he has a main theme with an immediate appeal to the imagination, of which he wishes to give a lucid exposition, and in relation to which he can select the most important material and arrange it in a coherent pattern without digressing too much over additional information. The alternative is to face the risk of presenting a hotchpotch of miscellaneous knowledge which it is hoped will be interesting or amusing. (It need hardly be added that the job should preferably be tackled for the sheer love of it, as the financial reward is not likely to be commensurate with the qualifications suggested).

Reading this book with such thoughts in mind, it loses points on all counts, and even by far less rigorous standards it could not be called more than a limited success. A first impression is that the translation is not altogether happy, the very title preparing the mind for this; a second, without having to

read very far, is that the original cannot have been the happiest of material to translate. There are interesting, informative, and moderately well written passages, some of them long, but the text is uneven and in other parts it abounds in statements which make one wonder what ought to be done about popularizers. One of the plums, for meteorologists, appears somewhat unexpectedly in the chapter on the oceans: ". . . the rainfall in Great Britain has been related to the temperature of the water in the vicinity of Newfoundland in the previous year. On this basis, long-term weather forecasts can sometimes be made for north-west Europe." Not the least interesting exercise to be derived from this quotation is to ponder on the exact meaning of "sometimes" in that context—whilst accepting, purely for the purpose of the exercise, everything else. The choice of word or phrase is frequently faulty, and though the translator may occasionally be to blame, it seems probable that the author is much more frequently guilty. The nadir is reached in a sentence rounding off the definition of cumulus: "Their contours are well defined and, fair-weather clouds as they are, it is upon them that the cherubs are reputed to frolic (Plate VII, 1)." The plate thus referred to reproduces a completely inoffensive photograph of large cumulus which is worthy of being brought to notice in a much more dignified way.

The plan of the book is ambitious. There is a brief introduction with a general discussion of the hydrological cycle and a summary of the special properties of water which make it "the most extraordinary of all compounds known to science"—an interesting conclusion which, even if not accepted, should not be underrated through a superficial familiarity with the substance. Then follow chapters with suitably "popular" headings running here and there through the fields of oceanography, hydrometeorology, cryology, geohydrology, and potamology and limnology, thus following the course of the major cycle. Examples in geomorphology are thrown in, for good measure, in the appropriate chapters, and indeed they provide some of the best material offered. The conclusion deals with the hydrological and salinity balance for terrestrial waters as a whole. It is obvious that to succeed in covering all this ground at all adequately in a book of this size, however popular the treatment, would be little short of miraculous. It is not surprising, therefore, that within the major framework, admirable as such, the subject matter of individual chapters is very "bitty" and sometimes takes disconcerting leaps. It is true that the author has given a warning about this in his foreword, and it might not be a serious fault in itself if the separate bits were always clear. Too often there are "explanations", sometimes of relatively simple ideas, which are laboured and confusing, and the frequent use of a certain type of phrase, usually "as we have seen", vaguely referring back to equally confused explanations, or merely to bald assertions, is not very helpful. It is a pompous didacticism which is used most and irritates most in bad teaching. The definition and discussion of capillarity, in dealing with soil moisture and ground water, extend over three pages, with diagrams, to constitute one of the least effective passages in the book. This is a great pity, the more so as there is a failure to provide any adequate treatment of water in the soil, and the reader without previous knowledge must inevitably be left with merely a hazy idea that it connects in some sort of way with ground water. After the barest mention of soil moisture, any water which is not in the ocean, in the atmosphere, or visible on the surface as snow, glacier, river or lake (with their smaller variations), tends to

become confused with ground water proper, or at best with the capillary zone immediately above the ground water table. But the behaviour and function of soil moisture are of the utmost significance in nearly all problems of land hydrology, and a very important "realm"—the most important for the social and economic life of the human race, and in fact for all animal and vegetable life on land—is thus lightly passed over.

The main theme of the book, that water passes continuously through a cycle, with sub-cycles, is probably too slender for a work of this kind. The theme with the resultant framework, enlarged to include a separate chapter on soil-moisture relationships, could make an excellent foundation for a serious textbook, but it cannot sustain the lengthy digressions which are necessary to treat the subject at large and at the same time retain a popular appeal. Again and again the volume is on the verge of becoming the "Tristram Shandy" of hydrology. Praiseworthy though it undoubtedly is for its intention, it fails through its own internal stresses set up by trying to shape a poorly prepared alloy in an unsuitable mould.

A. BLEASDALE

Prilog teoriji higrografa (*Zur Theorie des Hygrographen*). By Branko Maksić. *Abh. Abt. math. phys. tech. Wiss., Zagreb*, **1**, 1955, 11¼ in. × 8 in., pp. 41, *Illus.*

This pamphlet gives an elaborate discussion of the geometry of the hair hygrograph. It opens by finding a series in powers of relative humidity for the Gay-Lussac number, ratio $(l_u - l_0)/(l_{100} - l_0)$, where l is the length of the hair at relative humidity u. A series terminating at u^3 gives u from the Gay-Lussac number with an accuracy better than 1 per cent. over the whole range 0–100 per cent. and better than ½ per cent. over most of it. This series is then applied to the geometry of a hair hygrograph with the hair gripped by a hook at any point and moving the pen by a lever, as in the Fuess hygrograph, in which a short arm is fixed to the hook and a second carries the pen. Formulae giving displacements of hair and pen and the scale value in terms of relative humidity are determined. In fact the hook is approximately at the centre, and the formulae are used to examine the effects of zero adjustment obtained, as in the Fuess hygrograph, by moving one end of the hair towards or away from the other and altering the length of the short arm. Tables and diagrams of the corrections necessary after adjustment are provided.

G. A. BULL

OBITUARY

J. G. Balk.—We regret to report the sudden death on April 9, 1956, of Mr. J. G. Balk, who was an observer at the Radcliffe climatological station Oxford for 51 years, until his retirement in June 1954. During this long period of observing, rarely equalled, Mr. Balk gave the closest co-operation to the Meteorological Office, and maintained the highest standards of reporting. His note on the frequency of solar and lunar halos at Oxford, 1882–1951, published in the *Meteorological Magazine* in September 1952, was an instance of Mr. Balk's absorbing interest in weather recording. He will be remembered for the notable way in which he upheld the best traditions of the voluntary observing on which so much of the work of the Meteorological Office Climatological Branch depends.

METEOROLOGICAL OFFICE NEWS

Retirements.—*Mr. W. G. Davies*, Senior Experimental Officer, retired on April 30, 1956. He first worked at the Royal Observatory, Greenwich from 1909 until August 1914 when he joined the Armed Forces. He later transferred to the Meteorological Section of the Royal Engineers and was commissioned in December, 1918. He joined the Office in August 1920 and served for 11 years in the Forecast Division at Headquarters. Since 1932 he has served at aviation outstations and has spent no less than 12 years at overseas stations. For the last four years he has served at the Air Traffic Control Centre at Watnall.

At a ceremony at Watnall on April 28, Mr. J. Briggs presented Mr. Davies with a cheque subscribed by his colleagues.

Mr. W. F. Peatfield, Experimental Officer, retired on May 2, 1956. He joined the Office in May 1921 after serving in the First World War. From then until 1940 he served at aviation outstations and from 1940 to 1947 at Porton. For the last eight years he has worked at Harrow.

At a ceremony at Harrow on April 27, Dr. A. G. Forsdyke presented Mr. Peatfield with a cheque subscribed by his colleagues.

Mr. Peatfield has accepted a temporary appointment in the Meteorological Office.

Staff.—Under the terms of the Anglo Iraqi Agreement of 1955 the Meteorological Office at Shaibah has been transferred to the Iraqi Authorities and in consequence, the Meteorological Office has lost the valuable service of Mr. Raymond Fernandez. The Iraqi Authorities have re-engaged him with other locally employed meteorological staff, and he is Senior Observer in charge of the Office.

Mr. Fernandez was engaged as meteorological observer on April 1, 1932. His long experience was of great value to the more transient United Kingdom-based staff at Shaibah and the many meteorologists who have served in Iraq will doubtless remember him and wish him well in the future.

Ocean weather ships.—The following are extracts from reports of ocean weather ships:

Weather Explorer—Voyage 65 at station K. March 9 to April 2, 1956.

The fine weather brought on a revival of cricket; inter-section matches were fought with great spirit to the cheers and jeers of a very partisan crowd.

Weather Observer—Voyage 69 at station J. March 4–27, 1956.

On March 25, the French Weather Ship *Mermoz* passed close to, bound from Alfa to Base. One of the Radio Operators exercised his French on the R/T with his opposite number on the *Mermoz*; he must have done quite well as a bottle of wine was ditched, which we recovered, as a token of friendship.

WEATHER OF APRIL 1956

April showed strongly anticyclonic conditions dominating the northern polar regions with mean pressures up to 10 mb. above normal, in marked contra-distinction to March 1956 when the mean circulation over the central Arctic was cyclonic. Pressure in April was also above normal over the eastern Atlantic and British Isles, where the dry weather, cold in the eastern half, was reminiscent of April last year; the associated patterns over the rest of the hemisphere were, however, radically different in 1955 and 1956. Cyclonic activity over the North Atlantic in April 1956 was rather scattered, affecting different parts of the ocean (chiefly latitudes below 50°N. and the region Newfoundland–south Greenland) in different parts of the month, and was seldom deep. The most vigorous and regular cyclonic activity over the northern hemisphere appears to have been over the North Pacific. There were also rather low pressure and excessive rainfall (up to 2½ times the normal) in a strip across Europe from the western Mediterranean to the eastern Baltic, though there cannot be said to have been movement of depressions from south to north along this track; the systems were generally moving east and south-east or coming to a halt in this part of the map.

Pressure was 5 mb. below normal over Mexico, where there were also great excesses of rainfall at many stations. This seems to have been related to a long extension of the polar anticyclone southwards in longitudes about 105°W. (pressures up to 6 mb. above normal) and an abnormal southward displacement of the polar-front activity during most of the month in this sector.

The month was generally rather cold in Europe, except over Ireland and the Balkans, and in the Norwegian Sea (greatest anomalies −7°C. in east Greenland, −4°C. in Lapland and −3°C. in central Germany). Temperature was also below normal across the whole of northern Asia north of 55°N. and over most of North America except the Arctic zone and north-eastern segment (main anomaly centres −4° to −7°C. over the Prairies, but +3°C. in the region Baffin Land–northern Quebec).

Over the British Isles which, for the major part of the month, either lay within an area of ill defined pressure distribution or came under the influence of nearby anticyclones, there was a marked absence of vigorous cyclonic activity.

The month began with sunny weather over most of the country, but owing to a north-easterly air stream off the North Sea, it was dull and cold in the south-east. An anticyclone over the central Atlantic intensified on the 3rd and freshening northerly winds brought showers to most parts of the British Isles, with local thunderstorms, but on the 5th more widespread outbreaks of rain accompanied the passage of a wave depression southward across eastern counties; the following evening a renewal of northerly winds behind the depression brought snow showers as far south as Spurn Head. A depression near Iceland deepened on the 7th, and the associated westerly winds over this country brought four days of milder cloudy weather; there were periods of rain in western and northern districts, but in the south this was the warmest part of the month with temperature rising to the mid-sixties in many places. An influx of arctic air, associated with a deepening depression over the Baltic, caused a sharp fall of temperature on the 11th; in parts of East Anglia afternoon temperatures were as much as 20°F. lower than on the previous day. The northern boundary of the Atlantic air moved slowly south over Wales and southern England between the 12th and 14th giving prolonged rain, the only very wet period in southern England during the month. There was a rise of pressure to the west of Ireland on the 15th and a northerly flow soon became established over the country bringing showers to the north, but in the south it was dry and sunny. By the 18th an anticyclone was centred over Scotland, and from that date until the 23rd the weather was dry and rather cold with widespread ground frost and some keen air frost locally. Pressure however over the British Isles was slowly falling during this period, and by the 24th the anticyclone had disappeared allowing a renewed influx of arctic air; there was slight rain in many parts of the country with isolated thunderstorms, and on the following day rain was prolonged over northern England with snow in places, especially in Yorkshire where in the Pennines it lay locally to a depth of 6 in. From the 26th, low pressure over western and central Europe gave rise to rather cold N.—NE. winds over the British Isles, with some scattered showers and long sunny periods, but on the last day of the month warmer air from the Atlantic brought temperatures back nearer to the normal.

It was a generally cold month. In the Midlands and eastern half of England both night and day temperatures were 2–4°F. below normal, and in some districts near the east coast even as much as 5°F., but in western and northern districts day temperatures were mostly near the average though the nights were unusually cold. Sunshine, except in parts of the Midlands and south-east England, was considerably above average. Parts of Devon, Cornwall and Lincolnshire had 50 hr. more than normal and Tynemouth had its sunniest April since 1939. Rainfall was below average almost everywhere, many places had less than half their usual amount. The growth of crops and grass has been retarded by the dry cold weather but most farming operations have progressed without hindrance. Fruit blossom has been vulnerable to frost for much of the month, especially in south-east England, and some damage was caused as a result of the frosts on the nights of the 6th–7th and 19th–20th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	69	18	−2·8	75	−4	109
Scotland	65	18	−1·5	70	−2	124
Northern Ireland ...	63	25	−0·5	56	−4	112

RAINFALL OF APRIL 1956

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	1·16	75	*Glam.*	Cardiff, Penylan ...	1·85	74
Kent	Dover	0·74	46	*Pemb.*	Tenby	1·13	49
,,	Edenbridge, Falconhurst	1·40	75	*Radnor*	Tyrmynydd	2·30	62
Sussex	Compton, Compton Ho.	2·54	127	*Mont.*	Lake Vyrnwy	1·76	56
,,	Worthing, Beach Ho. Pk.	1·49	96	*Mer.*	Blaenau Festiniog ...	2·73	44
Hants.	St. Catherine's L'thouse	1·96	122	,,	Aberdovey	1·53	59
,,	Southampton (East Pk.)	2·03	110	*Carn.*	Llandudno	1·43	85
,,	South Farnborough ...	·93	61	*Angl.*	Llanerchymedd ...	1·92	87
Herts.	Harpenden, Rothamsted	1·10	67	*I. Man*	Douglas, Borough Cem.	1·11	45
Bucks.	Slough, Upton	1·15	80	*Wigtown*	Newton Stewart ...	2·30	90
Oxford	Oxford, Radcliffe ...	1·89	118	*Dumf.*	Dumfries, Crichton R.I.	0·97	41
N'hants.	Wellingboro' Swanspool	1·04	70	,,	Eskdalemuir Obsy. ...	1·05	31
Essex	Southend, W. W. ...	1·39	109	*Roxb.*	Crailing...	0·62	39
Suffolk	Felixstowe	0·66	55	*Peebles*	Stobo Castle	0·94	45
,,	Lowestoft Sec. School ...	0·81	55	*Berwick*	Marchmont House ...	0·72	36
,,	Bury St. Ed., Westley H.	0·97	63	*E. Loth.*	North Berwick Gas Wks.	0·44	32
Norfolk	Sandringham Ho. Gdns.	1·14	75	*Midl'n.*	Edinburgh, Blackf'd. H.	0·55	37
Wilts.	Aldbourne	1·77	90	*Lanark*	Hamilton W. W., T'nhill	0·76	41
Dorset	Creech Grange... ...	2·23	103	*Ayr*	Prestwick	0·90	52
,,	Beaminster, East St. ...	1·07	45	,,	Glen Afton, Ayr San. ...	1·64	55
Devon	Teignmouth, Den Gdns.	0·73	36	*Renfrew*	Greenock, Prospect Hill	1·97	57
,,	Ilfracombe	1·50	72	*Bute*	Rothesay, Ardencraig ...	1·78	60
,,	Princetown	2·14	42	*Argyll*	Morven, Drimnin ...	2·68	73
Cornwall	Bude, School House ...	0·76	40	,,	Poltalloch	1·60	53
,,	Penzance	0·68	28	,,	Inveraray Castle ...	3·65	79
,,	St. Austell	1·40	50	,,	Islay, Eallabus	2·29	80
,,	Scilly, Tresco Abbey ...	1·33	68	,,	Tiree	2·36	96
Somerset	Taunton	1·81	103	*Kinross*	Loch Leven Sluice ...	0·84	44
Glos.	Cirencester	2·61	135	*Fife*	Leuchars Airfield ...	0·74	47
Salop	Church Stretton ...	1·39	64	*Perth*	Loch Dhu	...	...
,,	Shrewsbury, Monkmore	1·53	103	,,	Crieff, Strathearn Hyd.	0·94	43
Worcs.	Malvern, Free Library...	1·71	95	,,	Pitlochry, Fincastle ...	0·81	36
Warwick	Birmingham, Edgbaston	1·53	80	*Angus*	Montrose, Sunnyside ...	1·24	68
Leics.	Thornton Reservoir ...	1·10	65	*Aberd.*	Braemar	1·58	67
Lincs.	Boston, Skirbeck ...	1·23	91	,,	Dyce, Craibstone ...	1·55	75
,,	Skegness, Marine Gdns.	1·15	86	,,	New Deer School House	1·24	62
Notts.	Mansfield, Carr Bank ...	2·05	118	*Moray*	Gordon Castle	1·72	98
Derby	Buxton, Terrace Slopes	2·28	78	*Nairn*	Nairn, Achareidh ...	1·95	139
Ches.	Bidston Observatory ...	2·76	169	*Inverness*	Loch Ness, Garthbeg ...	2·86	125
,,	Manchester, Ringway...	2·78	154	,,	L. Hourn, Kinlochhourn	5·85	94
Lancs.	Stonyhurst College ...	1·65	61	,,	Fort William, Teviot ...	3·89	86
,,	Squires Gate	1·35	76	,,	Skye, Broadford ...	2·99	66
Yorks.	Wakefield, Clarence Pk.	2·04	121	,,	Skye, Duntuilm ...	2·93	90
,,	Hull, Pearson Park ...	1·29	83	*R. & C.*	Tain, Mayfield... ...	2·27	124
,,	Felixkirk, Mt. St. John...	1·40	84	,,	Inverbroom, Glackour...	2·95	79
,,	York Museum	1·66	104	,,	Achnashellach	4·74	89
,,	Scarborough	0·76	49	*Suth.*	Lochinver, Bank Ho. ...	2·51	88
,,	Middlesbrough... ...	0·83	61	*Caith.*	Wick Airfield	1·69	85
,,	Baldersdale, Hury Res.	1·03	47	*Shetland*	Lerwick Observatory ...	1·66	72
Norl'd.	Newcastle, Leazes Pk....	1·36	85	*Ferm.*	Crom Castle	0·87	34
,,	Bellingham, High Green	0·85	39	*Armagh*	Armagh Observatory ...	1·07	51
,,	Lilburn Tower Gdns. ...	0·93	47	*Down*	Seaforde	1·93	74
Cumb.	Geltsdale	1·41	66	*Antrim*	Aldergrove Airfield ...	1·00	47
,,	Keswick, High Hill ...	1·20	39	,,	Ballymena, Harryville...	1·40	53
,,	Ravenglass, The Grove	0·91	37	*L'derry*	Garvagh, Moneydig ...	...	...
Mon.	A'gavenny, Plâs Derwen	2·16	78	,,	Londonderry, Creggan	2·01	78
Glam.	Ystalyfera, Wern House	1·16	31	*Tyrone*	Omagh, Edenfel ...	1·43	54

Printed in Great Britain under the authority of Her Majesty's Stationery Office
By Geo. Gibbons Ltd., Leicester

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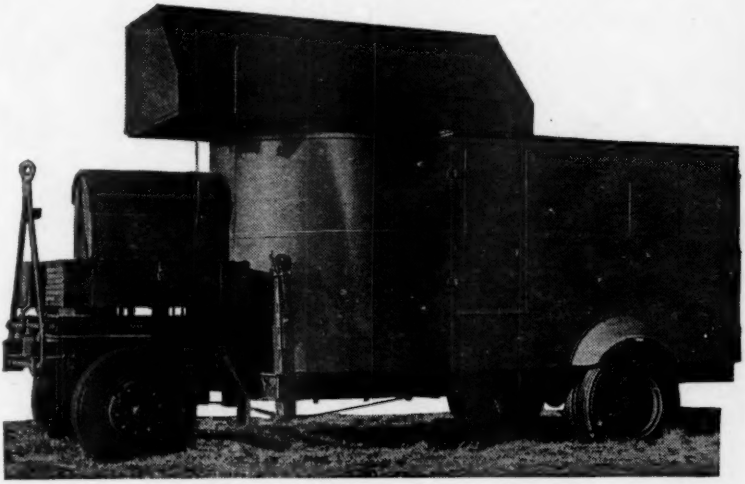

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